SIR Questions

1. Run sir\_sim\_test using the base scenario of R0=2.5, T=5, I0=0.001, V=0. Compare the days when the maximum number of new infections occurred and when the maximum infected population size occurred. Explain the time lag between these events.
2. Make a record of the maximum number of infectives and the day on which this occurs. Then change the initial fraction of infectives to 0.01 and record the changes in these two quantities. Go back to an initial fraction of 0.001 and observe how long it takes for the population of infectives to increase by a factor of 10, so as to reach 0.01. Use the results to draw conclusions about how a different initial number of infectives changes the course of an epidemic.
3. COVID-19 has a basic reproductive number of approximately 5. Set R0 to 5 (with initial infective fraction at 0.001) and describe the changes in the epidemic progress. Pay attention to the key output quantities and also the speed with which the epidemic develops and resolves. (Note: We are using the same basic reproductive number, but the SIR model with a 5-day disease duration is not a good match for COVID-19.)
4. The duration of COVID-19 infectivity is approximately 10 days rather than 5. Change the appropriate parameter and describe the effect this has on the progress of the epidemic. It is helpful to think of the end of the epidemic as roughly the point when the number of infectives is down to what it was initially. (Note: We still are not modeling COVID-19, because the SIR model fails to account for a long incubation period and asymptomatic transmission.)
5. The Incan Empire had a population of over one million when it was conquered by 168 Spanish Conquistadores in 1525. The Spanish had gunpowder weapons and horses, but these advantages would not have been sufficient to defeat the huge Incan army. (It took about 2 minutes to reload a single-shot arquebus.) They also benefitted by joining forces with peoples subjugated by the Incas, but that would not have happened on its own. In *Guns, Germs, and Steel*, author Jared Diamond argues that the key factor in the Incan defeat was the European diseases the Spanish brought with them. To test this theory, set the basic reproductive number at 5 and the duration at 20, values that roughly match smallpox. Describe the effect introduction of smallpox into Incan civilization would have had, even without considering the death toll of the disease.
6. For a more complete look at the effect of the basic reproductive number on epidemic progression, run SIR\_simplot using *β* values 0.5, 0.3, 0.2, 0.15, 0.125, with infectious duration 10 days and initial infectious fraction 0.001.
   1. Calculate the corresponding basic reproductive numbers and discuss the graphs.
   2. Suppose a disease with *R0*=5 is combated with social distancing and measures to decrease transmission probability for each contact. What effect do you expect these social policies to have and why?
7. Use SIR\_paramstudy to study the effect of the basic reproductive number on epidemic outcomes. Use *R0* values from 0 to 6 and default values for the other parameters. Describe and explain the results, paying particular attention to the behavior near *R0=*1.
8. Use SIR\_paramstudy to do a more thorough study of the effect of the disease duration on epidemic outcomes. Use *R0=*2.5. and *γ* values from 0.1 to 0.5. Describe and explain the results. Pay particular attention to the axis limits and the infectious durations corresponding to the *γ* values.
9. Vaccination grew out of a practice called “variolation,” the deliberate use of cowpox infection to confer immunity against smallpox, which was discovered independently in China in the 17th Century and by the English doctor Edward Jenner in 1796. Vaccination with killed pathogen began in 1798 and quickly replaced variolation. Determine how the proportion of pre-vaccinated individuals *V* affects the epidemic progress with the initial fraction of infectives at 0.001 and both the infectious duration and basic reproductive number at 5. Note that the best measure of the effect of vaccination is the fraction of the initially susceptible who eventually get the disease. SIR\_paramstudy does not currently calculate this quantity, but you can change the program so that it does. You will need to change the formula for Y(n,3) [*Y[n,3] in R*], and you should change the y axis label for the third plot.
10. There is some confusion in public discourse about the concept of herd immunity. This question will clarify the concept using sir\_sim\_test.
    1. Set the initial infectives to 0.001, the initial immunity to 0.75, the duration to 10 days, and the basic reproductive number to 4.13. Record the initial and final percentage of susceptibles.
    2. Change the initial immunity to 0 and record the initial and final percentages of susceptibles and the percentages of susceptibles and infectives on day 26.
    3. Explain herd immunity, focusing on what conditions need to be present to protect the susceptible population.
11. Isolation[[1]](#footnote-1) of the sick to combat infection dates back centuries, at least to the establishment of a leper colony in England in 1084. Our current model is inadequate to study isolation, so instead we use an SPUR model (Susceptible-Presymptomatic-Unisolated-Removed), where development of symptoms moves individuals either to the Removed class, for those who practice isolation, or the Unisolated class, for the rest.
    1. It is necessary to modify the programs to change from SIR to SPUR. Start by saving copies of sir\_sim, sir\_sim\_test, and SIR\_paramstudy as spur\_sim, spur\_sim\_test, and SPUR\_paramstudy. Then make the appropriate changes to spur\_sim and spur\_sim\_test, as described in the instructions.
    2. Describe and discuss the effect of isolation of symptomatic infectives on the fraction of people who avoid getting the disease.
    3. Change Tp to 4. Describe and explain the difference this makes.
    4. Use your results to discuss the effectiveness of isolation for diseases with different properties.

1. The word ``quarantine’’ is often used incorrectly for the practice of isolation. Quarantine is the practice of isolating individuals who are thought to have been exposed to a disease, not individuals who are showing symptoms. [↑](#footnote-ref-1)